Journal of Cleaner Production 198 (2018) 1–10

Contents lists available at ScienceDirect

Journal of Cleaner Production

journal homepage: www.elsevier.com/locate/jclepro

Between rainfall and food poverty: Assessing vulnerability to climate change in an agricultural economy

Olawale Emmanuel Olayide [a, *], Tunrayo Alabi [b]

[a] Centre for Sustainable Development, University of Ibadan, Ibadan, Nigeria
[b] International Institute of Tropical Agriculture (IITA), Ibadan, Nigeria

ARTICLE INFO

Article history:
Received 3 March 2017
Received in revised form
2 June 2018
Accepted 20 June 2018
Available online 30 June 2018

Keywords:
Rainfall variability
Food poverty
Geographical information systems
Adaptation policy

ABSTRACT

The agricultural sector in Nigeria provides a socio-economic resource base for exiting pervasive poverty, and transforming the economy. However, with the challenges posed by climate change through variability in rainfall, the agricultural livelihoods and poverty status of the population could be threatened due to the vulnerability context of the country. This paper explores the relationship between rainfall and food poverty through the assessment of vulnerability to climate change in an agricultural economy by geo-referencing and mapping of rainfall variability and food poverty. It provides a quantification of the scale and location of the area under food poverty and rainfall variability with scenarios that provide alternative sustainable development pathways of desirable outcomes. The coefficients of variation of rainfall or precipitation seasonality were computed from geo-referenced data and topologically overlaid on the most recent food poverty profile for Nigeria. The findings reveal intriguing phenomena bordering on agro-climatic and socio-economic factors of climate change vulnerability. The findings provide a basis for policy formulation and implementation on inequity of food poverty and environmental sustainability. It offers empirical insights on how to rethink concepts of socio-economic and environmental sustainability through landscapes and livelihoods as outcomes of vulnerability contexts. The paper concludes that, there is need for agricultural transformation along vulnerability dimensions. The evidence of the nexus between rainfall and food poverty could be a new model for promoting sustainability of the agrarian economy in Nigeria.

1. Introduction

Nigeria is an agrarian economy (World Bank, 2008). The agricultural sector contributed 46.71 percent to the national gross domestic product (GDP) in the third quarter of 2017 (NBS, 2017). This agrarian economy is largely rain-fed (Olayide et al., 2016a & 2016b). The changes in the mean and variability of rainfall affect the hydrological cycle (onset and cessation) of rainfall. Such changes would have significant effects on rain-fed agricultural and food production systems. Further, variability in rainfall (increase and/or decrease) can be expected to intensify the cycle of poverty in an agrarian economy like Nigeria (Kristjanson et al., 2012; Kurukulasuriya et al., 2006). An exploration of the nexus of rainfall variability and food poverty would be important for appropriate understanding of the temporal and spatial conditions of the situation, and for policy intervention for Nigeria, which is Africa's most populous and largest economy.

The potential growth-enhancing nature of agriculture through agricultural contribution to gross domestic product (GDP) in Africa is well documented (Christiaensen et al., 2006). However, the nexus of agricultural system, food poverty and climate vulnerability are inextricably linked. Such that whatever gains might be recorded in agricultural growth during a certain period can easily be eroded through climate change impacts (World Development Report, 2010; Heltberg et al., 2008; Raleigh et al., 2008; Morton, 2007). Similarly, complex interactions and impacts of climate variability are even more far-reaching due to bi-economic and environmental attributes of the agricultural production systems. Agriculture production (crops, livestock, fisheries, and forestry) are vulnerable to climatic changes (Olayide et al., 2016b; Brugère and De Young, 2015; Cervigni et al., 2013), Hence, the quantitative determination of the dynamic and complex nature of these intricate interconnections on landscapes and livelihoods would require simplification in order to communicate research findings to diverse

* Corresponding author.
E-mail addresses: waleolayide@yahoo.com, oe.olayide@ui.edu.ng (O.E. Olayide).

https://doi.org/10.1016/j.jclepro.2018.06.221
0959-6526/

stakeholders (Siwar et al., 2009). Often, policymakers need to understand the magnitude and effect of the interactions through simplification and interactive mapping of the outcomes of these interactions for ease of policy framing and implementation on a national scale. Therefore, the methodology of geographical information systems and mapping is apposite for understanding the nexus between precipitation and poverty in Nigeria. The two variables (precipitation and poverty) are entrenched in the sustainable development goals (SDGs) 1, 2 and 13 of the United Nations (UN, 2015). Specifically, SDGs 1 and 13 call for a world without poverty, and the need for climate actions, respectively. These SDGs also fall within the socio-economic and environmental dimensions of the SDGs as well as economic growth and well-being of populations (Filho et al., 2018). Therefore, it is imperative to analyse the nexus of the variables given their important considerations in rain-fed agriculture and food systems in the most populous nation in Africa - Nigeria.

The natural resource base of agricultural production (rainfall) is becoming more erratic, scarce and continuously changing (Rosegrant et al., 2014; Fjelde and von Uexkull, 2012). The paradox of Nigeria's agriculture production systems is that it is more dependent on natural base (rainfall). Hence, rainfall is important for the overall economic growth (including poverty reduction), since rainfall anchors agriculture which is the mainstay of the Nigerian economy (NBS, 2017). This is to the extent that extreme weather conditions like flooding and drought result in huge economic losses to the nation. For instance, the 2012 floods alone resulted in an estimated US$16.9 billion (FGN, 2013).

Further, with renewed focus on the agricultural sector as the engine of economic growth and diversification of the economy comes the challenge of climate change which has the potential of impacting negatively on the rain-fed agricultural production systems in the country. Hence, the study topologically investigated the interactions of rainfall variability and food poverty. The food poverty index is the caloric equivalence of the monetary poverty index (NBS, 2016). The caloric equivalence of poverty is preferred to monetary (income or expenditure) equivalence since the caloric equivalence measure of poverty is related to food security, nutrition, hunger, climate change, human development, and the sustainable development goals (United Nations, 2015). Besides, income or expenditure measure of poverty could lead to inconsistent patterns for geo-referenced data, and as such become grossly insufficient to capture contextual vulnerability (Fjelde and von Uexkull, 2012).

Agricultural production systems in sub-Saharan Africa, particularly in Nigeria, depend largely on rainfall and expansion of arable land. This system of agricultural production is not sustainable given the current challenge of climatic variability. It has been noted (Fjelde and von Uexkull, 2012) that erratic rainfall reduces the availability of water resources and arable land for agriculture.

Agriculture and poverty are the potential areas of vulnerability to climate change variable, especially rainfall variability in an agrarian economy (Olayide et al., 2016a; Brugère and De Young, 2015). Climate change variables and socio-economic situations are intricately linked in a vulnerability context. Since the agricultural production system in Nigeria is predominantly rain-fed (Olayide et al., 2016b), the analysis of the nexus of rainfall variability and food poverty offers an important policy research for evidence-based policy in reducing the impacts of climate variability, and improving human welfare (DFID, 1999). Hence, the methodological innovation of geographical information system mapping of the results confer additional advantage of simplicity and clear communication to policy actors (Olayide and Alabi, 2013; Vermeulen et al., 2012; Fjelde and von Uexkull, 2012; Legg, 2007).

Theoretically, the impact of climate change is in the domain of vulnerability assessment (IPCC, 2015; Oppenheimer et al., 2014). Food poverty which often results from existing inequalities (or deprivation/lack of production capital) in resource distribution and access, or the control individuals exert over choices and opportunities and historical patterns of social domination or marginalization, could be further altered or aggravated by climate change impacts on the agriculture through rainfall variability. Two schools of thoughts have emerged in literature in respect of vulnerability assessment. These schools of thoughts are the contextual and climatic vulnerability assessments. The contextual or socio-economic outcome vulnerability which deals with the socio-economics (including poverty) analysis while the climatic vulnerability assessment deals with projected impacts of climate change (including rainfall) variability analysis (Brugère and De Young, 2015; Oppenheimer et al., 2014; O'Brien et al., 2007; O'Brien et al., 2007). However, these two methodologies of vulnerability assessment (contextual vulnerability and climatic vulnerability) are not independent but related in the anthropogenic space (Filho et al., 2018).

Variability in climate has immediate and remote consequences for agricultural production outcomes (Cooper et al., 2006). Hence, the paper explored the nexus of rainfall variability in explaining uncertainty in agricultural production for an economy that depends largely and significantly on the rain-fed agricultural system of production. Further, vulnerability of agricultural livelihoods to climate change variability transcends continents and economies. However, least developed continents with agricultural-based economies seem to be more impacted, and the vulnerability impact of climate change in rain-fed agricultural economies are significantly predicted to be higher than developed industrialized economies (IPCC, 2015; Ahmeda et al., 2011; Challinor et al., 2007; Mirza, 2003).

This paper explores the relationship between rainfall and food poverty through the assessment of vulnerability to climate change in an agricultural economy by geo-referencing and mapping of rainfall variability and food poverty which includes the quantification of scale and location of food poverty and rainfall variability with scenarios that provide alternative sustainable development pathways of desirable outcomes.

This rest of this paper is organised into five sections comprising: review of approaches for assessing climatic variability and poverty, materials and methods, results, discussion, conclusion and recommendations.

2. Approaches to climatic variability and poverty assessment

Approaches adopted in previous studies on climatic variability and poverty assessment are varied. Generally, the approaches focus on conceptualisation and operationalisation of the context and climatic variability in the areas of data, analytical techniques and presentation of results. In the area of data, most studies have concentrated on household-level data to estimate vulnerability to climate variability (Gentle and Maraseni, 2012; Hahn et al., 2009). In other studies (IPCC, 2015; Sanchez, 2000), time series data have been used to provide information on the relationship between vulnerability context (including food security and poverty) and climatic variability. The form of data procedure could also said to be quantitative (numerical) or qualitative (narrative) or mixed-methods which combines quantitative and qualitative methods. The qualitative approach includes participatory social research methods such as climate vulnerability and capacity analysis as used in the analysis of the coping strategies of different wellbeing groups by Hertel and Rosch (2010). Data analytical techniques could also be descriptive, inferential or mixed-methods. In practice, there are many variants of descriptive and inferential analyses. The

descriptive analysis could involve basic frequency analysis and narratives. While inferential analysis broadly encapsulates statistical analysis that draws relationship between two or more variables. These forms of inferential analyses include correlation and regression analyses. Usually, mixed-methods of data procedure and/or analysis provide more advantages and perfectives over a single form of data or analytical technique.

Other broad categories of approaches used in the analysis climate change variables on agriculture include: regression-based or causal relations (Filho et al., 2018; scenario analysis (IPCC, 2015); simulation and impact analysis (Rosegrant et al., 2014). However, the imperatives of the approach of topologically analysing rainfall variability and food poverty using geographical information systems offers robust results for ease of communication to policymakers and stakeholders for priority-setting and targeting of climate change adaptation and resilience interventions.

Various studies have previously attempted to provide a link between climate change and poverty (Hertel and Rosch, 2010; Hahn et al., 2009; Hope, 2009; Fischer et al., 2005; Sanchez, 2000). In the study by Hahn et al. (2009), cross-sectional dataset (including, water resources and socio-demographic structure) was used to develop livelihood vulnerability index to estimate climate change vulnerability in the Mabote and Moma Districts of Mozambique. Their findings suggested that Moma may be more vulnerable in terms of water resources while Mabote may be more vulnerable in terms of socio-demographic structure. Hence, justifying that difference situations portend different approaches and policy scenarios for climate change adaptation (Hertel and Rosch. 2010), and the need for a methodological approach that considers the multiplicity of interactions and scenarios in climatic variability and agricultural livelihoods.

Similarly, the poor has low capacity to adapt to inevitably changing climate. Hence, policy to enhance socio-economic development of the poor should be well-targeted. Hope (2009) reported and analysed the relationship between climate change and poverty in Africa but neither emphasised nor analysed the relationship between rainfall variability and food poverty in the specific context of Nigeria, which is the most populous country in the continent of Africa. Besides, Hertel and Rosch (2010), suggest that quantification of the impact of climate change on agriculture and poverty especially in poor countries. The changing climate is an additional burden to the poor people who are vulnerable and engaged in rain-fed agricultural livelihoods (Olayide et al., 2016b; Gentle and Maraseni, 2012).

Further, climate change impacts on agriculture through food and agricultural production systems (IPCC, 2015; Hertel and Rosch, 2010; Fischer et al., 2005). The impact of climate change also varies by location and sector of the economy (Gentle and Maraseni, 2012; Hertel and Rosch, 2010; Sanchez, 2000; Hardoy and Pandiella, 2009). Therefore, the geographical information system-based approach as employed in this study provides a mixed methods framework for combining agricultural livelihoods outcome (food poverty) and climatic variable (rainfall variability) matching procedures to identify specific agro-ecological and socio-economic limitations under various scenarios of the geography of agrarian economy in Nigeria.

Further, while some previous studies provide mixed methods of data and analysis, less attention is often paid to estimating the landscape or coverage of the impact of climate variability and food poverty. This paper, therefore, differs from previous studies. It provides an extension of the body of knowledge by analysis data on rainfall variability and food poverty to underscore the importance of livelihoods (agricultural economy) and landscape (geo-referencing and mapping) in the assessment of rainfall variability and food poverty. Similarly, this paper is unique in the specific area of the use of current dataset, robust analytical technique and presentation of results in a way that informs policy formulation and implementation on inequity of food poverty and environmental sustainability.

3. Materials and methods

The study employed disaggregated data by the 36 States and Federal Capital Territory of Nigeria. The food poverty dataset was extracted from the databases of the National Bureau of Statistics (NBS) of the Federal Government of Nigeria. The rainfall data was obtained from the University of East Anglia Climate Research Unit-Time Series (CRU-TS 3.1) climate data (Harris et al., 2014) as well as the Climate Hazards group Infrared Precipitation with Stations (CHIRPS) dataset (Funk et al., 2015). The CRU data was of coarser spatial resolution of 0.5° while the CHIRPS data was at a finer spatial resolution of 0.05°. Hence the CRU data was only used for the year 1970–1980 for which CHIRPS data were not available. Monthly rainfall grids were summed to annual totals from which the mean and standard deviation were computed. The coefficient of variation which is a measure of spread that describes the amount of variability relative to the mean was then computed. The geographic information system (GIS)-based analysis was undertaken using ArcGIS 10.4 software package.

Rainfall variability was examined on annual and seasonal (July to September) basis for the entire study period of 1970–2015. A ten-year period (decadal) analysis (1971–1980, 1981–1990, 1991–2000, and 2001–2010) was done to examine rainfall variability within the main agricultural activity or crop growing season for the study period (including maps of seasonal rainfall distribution).

Three stages were involved in the process of mapping. First was the poverty map, followed by the rainfall variability map, and later the overlay of both the poverty map and the rainfall variability map. Food poverty data (2010) and coefficient of variations of corresponding annual rainfall dataset (1970–2015) were categorized into three groups (low, moderate, and high) for each. The coefficient of variation (CV) is a measure of the relative dispersion of a series of data around its mean. It is defined as the ratio of the standard deviation to the mean. It is often used to compare the degree of variability between series. The greater the coefficient of variation is, the greater the dispersion to the mean or variability of the data. The CV was calculated as follows:

$$CV = \frac{\sigma}{\mu} \tag{i}$$

where σ is the standard deviation and μ is the mean of the series. The standard deviation (σ) was obtained as follows:

$$\sigma = \sqrt{\frac{1}{N}\sum_{i=1}^{N}(x_i-\mu)^2} \tag{ii}$$

Overall, the analytical steps involved computation, categorisation, and mapping of the variability of rainfall data and food poverty data. The categorisation of food poverty and rainfall variability into three groups of low, moderate and high was obtained using the combination of mean (average) and standard deviation ($X \pm SD$) of the poverty data (low food poverty is less than mean minus standard deviation; moderate food poverty is range of mean and standard deviation; and high food poverty is greater than mean plus standard deviation). The categorisation of rainfall variability was informed by the nature of the data, and are specified in the legends of the maps. Generally, the categorisation of rainfall variability was based on specific range of the coefficients of variation

scaled up to 100 percent (where low rainfall variability is less than 15 percent; moderate rainfall variability is 16–20 percent; and high rainfall variability is greater than 21 percent). The coefficients of variation for the annual rainfall data for the study period were adjusted accordingly to fit the range of the dataset.

4. Results

4.1. Decadal ainfall variability

The results of the decadal rainfall variability within the main agricultural production or crop growing season (July–September) reveal that the pattern of rainfall in Nigeria has been very unstable. The period from 1971 to 1980 revealed that Bayelsa, Delta, Imo, Abia, Cross River, Benue, Taraba, Adamawa, Plateau, Adamawa, Gombe, Bauchi, Kaduna, Niger, Nassarawa, Zamfara, and the Federal Capital Territory have low rainfall variability (see Map 1). Low rainfall variability is the desirable condition for adequate agricultural planning and sustainable agricultural production. However, climate variability is implicated when wide variations are observed over a period of time (Olayide et al., 2016b). In this instance, results revealed high rainfall variability in the northern and southern part of Nigeria (almost at the extreme regions of the country in the north-east and the south-west. The north-eastern parts comprise Jigawa, Yobe and Borno while the southwestern parts comprise Lagos, Ogun, Oyo, Osun, Ondo, Ekiti and parts of Kwara, Edo and Kogi). Generally, the southern part has bimodal rainfall distribution while the northern part has unimodal distribution of rainfall. The average peak period over the country is between July and September which corresponds to the main production or crop growing season from the south to the north. The high variability in rainfall in the north is symptomatic of drought while high variability of rainfall in the south is symptomatic of flooding. These two extreme weather events (droughts and flooding) have increased in frequency and intensity in Nigeria (Olayide et al., 2016a; Adeoti et al., 2010).

Table 1
Area and percentage area under decadal rainfall variability for July–September (in square kilometers).

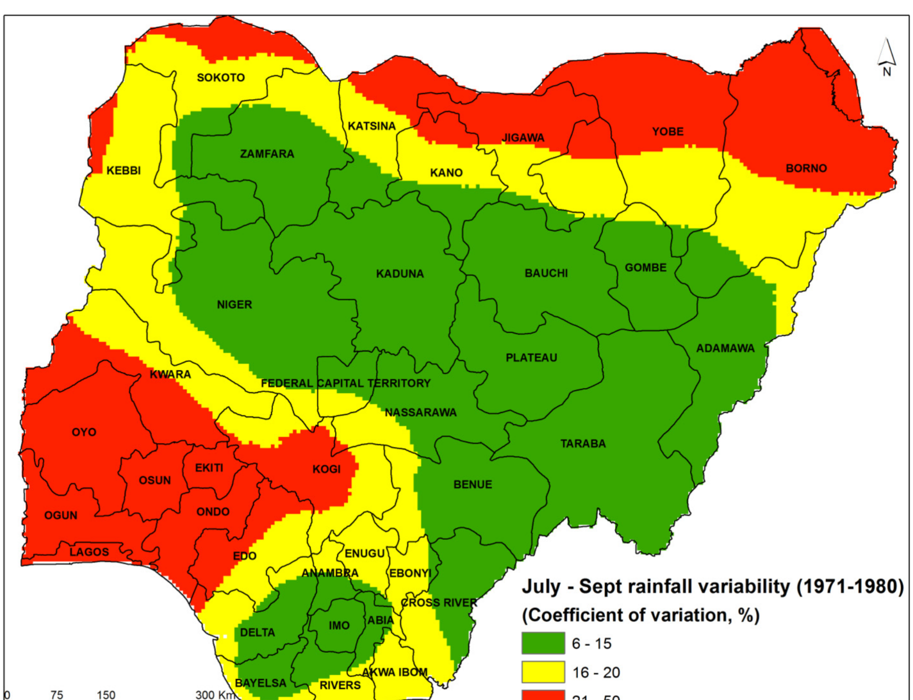
Decade	Low	Moderate	High
Area covered in square kilometers			
1971–1980	425,726	252,794	242,880
1981–1990	437,548	283,827	202,087
1991–2000	667,867	221,422	34,174
2001–2010	690,219	145,716	87,528
Percentage of area covered (%)			
1971–1980	46.2	27.4	26.4
1981–1990	47.4	30.7	21.9
1991–2000	72.3	24.0	3.7
2001–2010	74.7	15.8	9.5

Similarly, the rainfall variability during 1981–1990 revealed that Akwa Ibom, Abia, Cross River, Benue, Taraba, Adamawa, Plateau, Gombe, Bauchi, Kaduna, Niger, Kebbi, Zamfara, and the Federal Capital Territory had low rainfall variability. While Bayelsa, Delta, Edo, Ondo, Osun, Lagos, Ogun, Oyo, Kano, Yobe, and Borno recorded high rainfall variability over the period.

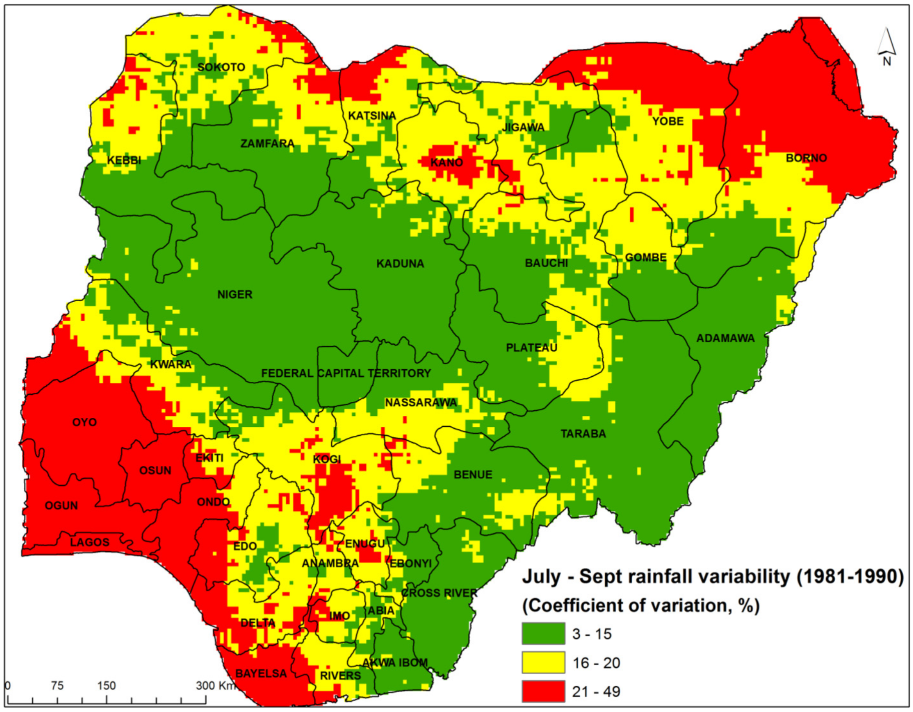
However, there were improvements in the rainfall variability for the period of 1991–2000. Significant portion of the States (more than 70 percent of the landscape of the country) recorded low rainfall variability. Given climate variability and change, this period could be regarded as a clement period for food production in Nigeria.

The results of the decadal rainfall variability for the period 2001–2010 revealed certain pattern similar to the period 1981–1990. This pattern was more obvious for the southern part of the country especially in some southern States like Bayelsa, Delta, Edo, Ondo, Osun, Lagos, Ogun, and Oyo which recorded high rainfall variability.

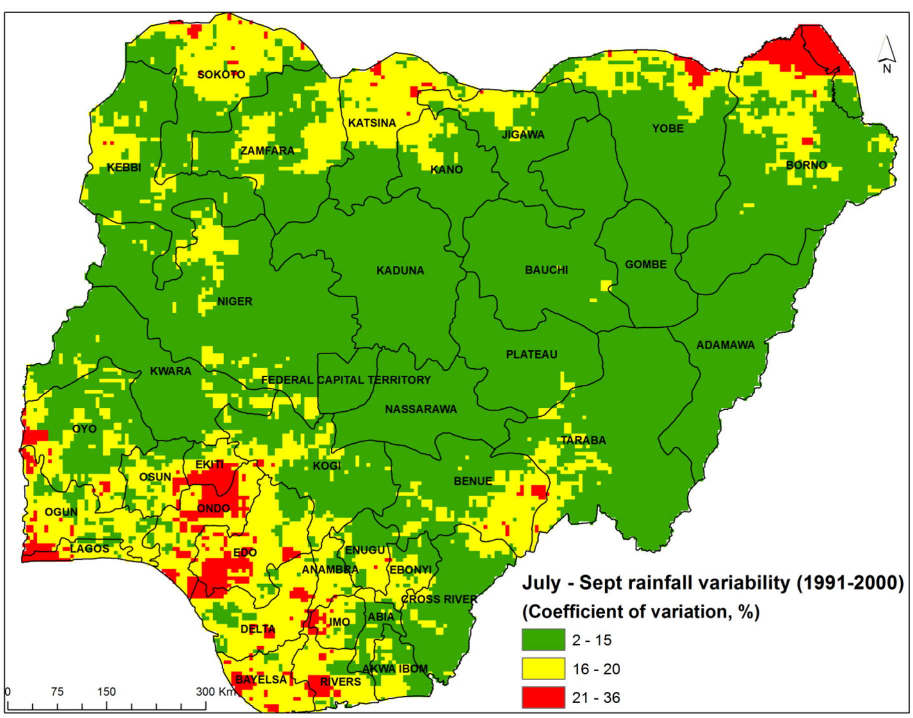
Table 1 summarises the decadal variability in rainfall (Maps 1-4). The results show a consistent trend from low variability to high variability. The area covered (in square kilometers) also varied



Map 1. Decadal rainfall variability, 1971–1980.

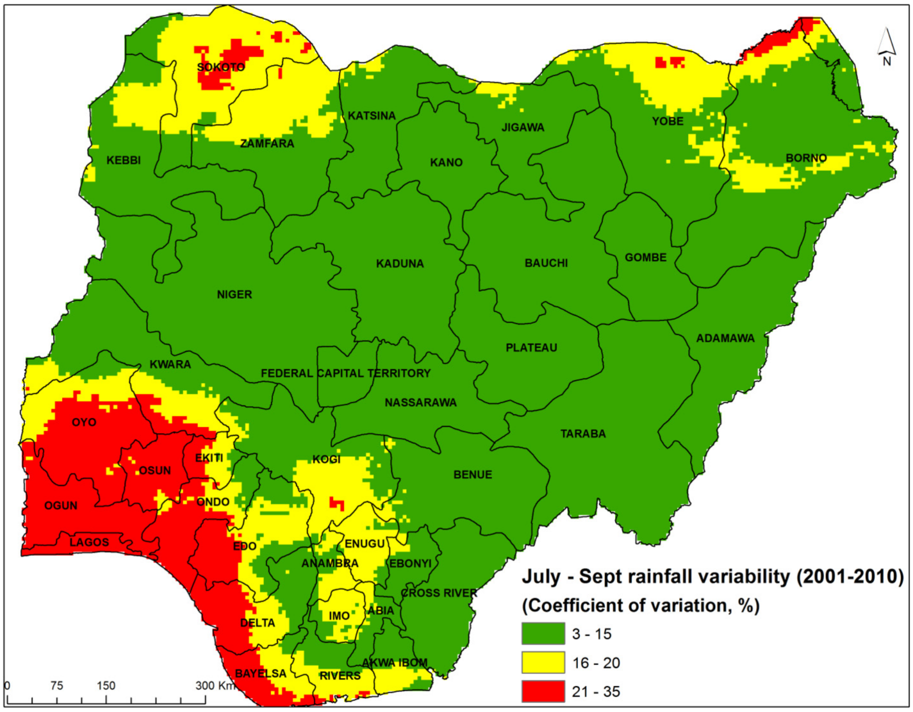


Map 2. Decadal rainfall variability, 1981–1990.



Map 3. Decadal rainfall variability, 1991–2000.

from one decade to another. The decade of 1991–2000 had the lowest area of high rainfall variability (3.7 percent). The level of low rainfall variability increased from 46.2 percent during 1971–1980 to 74.7 percent during the period of 2001–2010 (see Table 1). While increasing the areas of land and percentage under low rainfall variability is most desirable, the results show that there have been consistent increases in the area under low rainfall variability on decade-to-decade basis. However, the areas of land under moderate to high variability are not consistent over the period of the study. Therefore, policy on climate change adaptation should be well targeted at the landscape of high vulnerability (high variability) in order to progressively reduce the level of vulnerability in the country, and to consistently improve on the magnitude to land area under low rainfall variability.

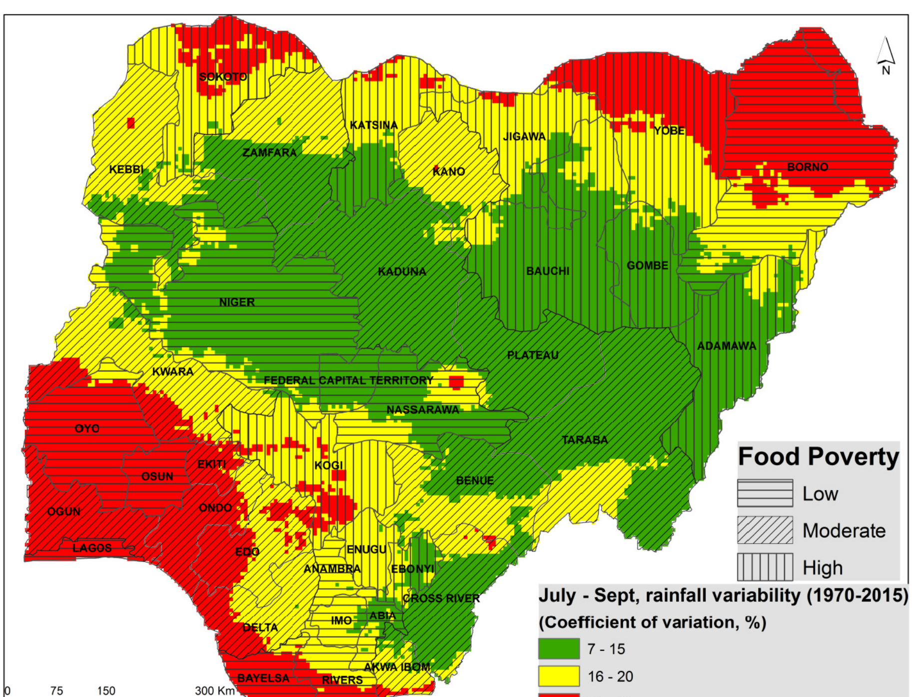


Map 4. Decadal rainfall variability, 2001–2010.

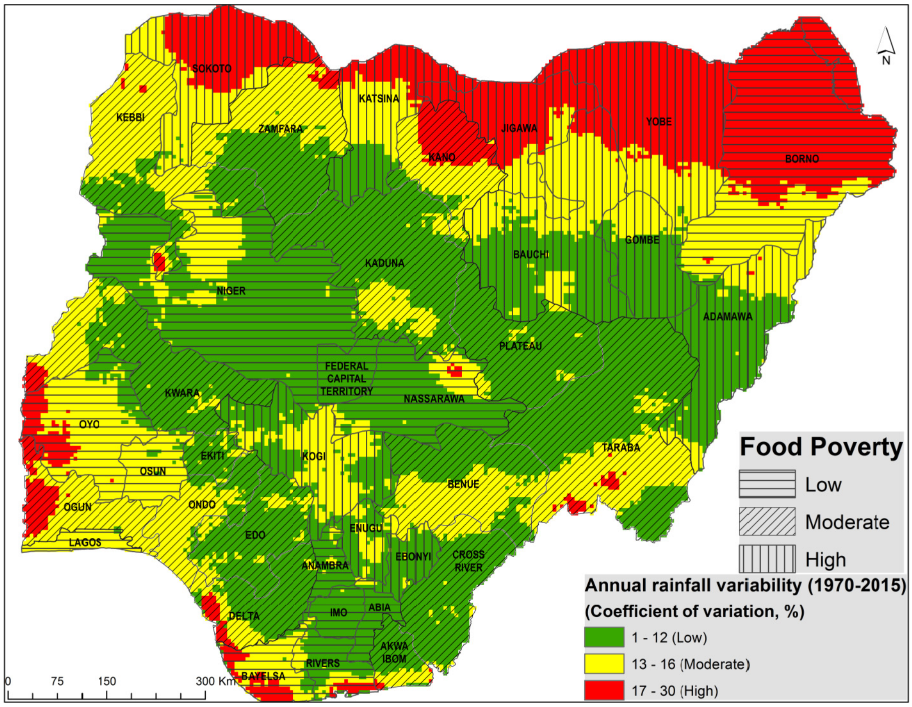
4.2. Rainfall variability and food poverty

Having established the level and magnitude of land areas under rainfall variability, the study proceeded to overlay rainfall variability and food poverty (Maps 5 and 6). The results reveal that rainfall and food poverty are intricately linked. This evidence is consistent with recent literature (Brugère and De Young, 2015) and supports the hypothesis on the synergy in contextual vulnerability and climatic vulnerability. Niger, Federal Capital Territory and Nasarawa are the locations with low rainfall variability and low food poverty (LRVLFP) for the July–September rainfall variability.

On the annual rainfall variability (Map 6), the most undesirable high rainfall variability and high food poverty (HRVHFP) occurred in the core northern States of Sokoto, Jigawa, Yobe, and Borno,



Map 5. Food poverty and peak rainfall variability, 1970–2015.



Map 6. Food poverty and annual rainfall variability, 1970–2015.

while Niger, Federal Capital Territory and Nasarawa remained the locations with low rainfall variability and low food poverty (LRVLFP). None of the States in the southern part has high rainfall variability and high food poverty status.

Generally, the locations with low to moderate rainfall variability also have low to moderate food poverty. While locations of high rainfall variability have high food poverty, and they are in the sahel region of the country. Again, these results suggest the important link between rainfall variability and food poverty. It also gives the direction for appropriate policy interventions on food poverty reduction strategies which may include irrigation and climate smart agricultural practices.

The results in Table 2 reveal the magnitude of the areas (and percentages) under the combined effect of rainfall variability and food poverty. The peak period of rain season (July–September) was the highest area under low rainfall variability and moderate food poverty. There is a consistent increase from the domain of high food poverty to low domain of food poverty. The results show increasing magnitude of land area covered by the interactions of rainfall variability and food poverty. The domain of high food poverty and high rainfall variability (HpHr) covered 4.9 percent of the land area, the domain of moderate food poverty and high rainfall variability (MpHr) covered 6.4 percent of the land area, while the domain of low food poverty and high rainfall variability (LpHr) covered 6.4 percent of the land area. Overall, there is a consistent pattern of increases in the magnitude of land area under food poverty during the peak of rain season. On the other hand, consistent pattern for the entire study period (1970–2015) is explained by rainfall variability. Similarly, there is consistent increment in the magnitude of land area under the combined interactions of food poverty and rainfall variability across the domains traversing from high rainfall variability to low rainfall variability for any of the combination with food poverty. For instance, the results show that the domain of the domain of low food poverty and high rainfall variability (LpHr) covered 6.6 percent of land area, the domain of low food poverty and moderate rainfall variability (LpMr) covered 8.3 percent of land area, while the domain of low food poverty and low rainfall variability (LpLr) covered 12.6 percent of land area. A further inferential statistical analysis using Chi square tests of the categorical level (low, moderate and high) of the variables of food poverty and rainfall variability revealed a weak significant level of positive relationship (value = 7.600; p = 0.107) but a strong significant and positive linear-by-linear association (value = 3.978; p = 0.046). Hence, there is evidence that variability in rainfall is connected with food poverty in Nigeria.

Table 3 provides the summary of the various scenarios and analysis of the hotspots of rainfall variability and food poverty in Nigeria. Again, the locations or administrative areas (States) vary from the most desirable outcome of low rainfall variability and low food poverty (LRVLFP) comprising the locations in Rivers, Imo, Abia, Anambra, Nassarawa, FCT-Abuja, and Niger to the least desirable outcomes of high rainfall variability and high food poverty ((HRVHFP), comprising the locations in Sokoto, Katsina, Jigawa, Yobe and Borno. Hence, these results are instructive for adequate adaptation policy strategies in Nigeria.

Table 2
Areas under July–September rainfall and poverty analysis and area under annual rainfall and poverty analysis.

Poverty class	Map 5			Map 6		
	Rainfall variability class			Rainfall variability class		
	Low	Moderate	High	Low	Moderate	High
Low	93,589	57,029	99,143	114,343	75,670	59,666
Moderate	189,010	141,672	58,045	236,613	132,885	19,137
High	106,597	117,401	44,428	94,692	92,818	81,110
Total	389,196	316,101	201,616	445,647	301,373	159,914
	Percentage (%)			Percentage (%)		
Low	10.3	6.3	10.9	12.6	8.3	6.6
Moderate	20.8	15.6	6.4	26.1	14.7	2.1
High	11.8	12.9	4.9	10.4	10.2	8.9
Total	42.9	34.9	22.2	49.1	33.2	17.6

Table 3
Hotspots of rainfall variability and food poverty in Nigeria.

Rainfall Variability (RV)	Food Poverty (FP)		
	Low	Moderate	High
Low	Rivers, Imo, Abia, Anambra, Nassarawa, FCT-Abuja, and Niger (LRVLFP)	Delta, Akwa-Ibom, Cross River, Benue, Taraba, Plateau, Kaduna, Kwara, Kebbi, and Zamfara (LRVMFP)	Kogi, Adamawa, Gombe, Bauchi and Katsina (LRVHFP)
Moderate	Oyo, Osun, Lagos, Adamawa, Bayelsa and Borno (MRVLFP)	Ogun, Ondo, Edo, Kwara, Benue, Taraba, Kebbi, Zamfara, Kano, and Kaduna (MRVMFP)	Enugu, Kogi, Adamawa, Gombe, Bauchi, Katsina, and Sokoto (MRVHFP)
High	Oyo, Bayelsa and Rivers (HRVLFP)	Ogun, Delta, Taraba, and Kano (HRVMFP)	Sokoto, Katsina, Jigawa, and Yobe (HRVHFP)

5. Discussion

Desirability, vulnerability, and sustainability

The decadal and long-term data analysis of rainfall variability gives the indication of the nature and pattern of seasonality and drivers of rain-fed agricultural production systems prevalent in Nigeria. The northern part of the country with uni-modal pattern of rainfall distribution is predominantly cereal-legume-based cropping system with ruminant production systems (mostly cattle, including sheep and goats) (Sebastian, 2014; Manyong et al., 2005). While the southern part of the country has bimodal rainfall distribution with roots and tubers based cropping system with significant production of poultry and aquaculture. Although, low rainfall variability is desirable for sustainable agricultural and food production systems, the reality (as shown by the results of the analyses) is that moderate to high variability (and vulnerability) prevails in most parts of the country with the exception of Rivers, Imo, Abia, Anambra, Nassarawa, FCT-Abuja, and Niger which have low rainfall variability and low food poverty status (LRVLFP).

Interestingly, both extremes of the northern and southern parts of the country exhibit extreme rainfall variability with Sokoto, Katsina, Jigawa, Yobe and Borno having high rainfall variability and high food poverty status (HRVHFP); all of which are in the northern part of the country. The northern part is close to the sahel while the southern part is in the coastal area (Atlantic ocean). Some studies (IPCC, 2015) have predicted a higher frequency and intensity of rainfall in the southern/coastal locations while low frequency and intensity of rainfall is predicted for the northern locations. Both extreme locations with extreme rainfall patterns and conditions portend negative vulnerability outcomes on overall food security with a high probability of food poverty in Africa's most populous country.

The findings of this study are also supported by recent literature on impact of climate change on agriculture and food systems (Montpellier Panel Report, 2015) that suggests that negative impacts of climate change (including, rainfall variability) on food security in Africa, especially in Nigeria. For instance, the major flooding incidences reported in Nigeria (Olayide et al., 2016a; Odufuwa et al., 2012) occurred in the harvest season which is usually during August and October. Thus, even when the farmers are able to adjust or adapt to late onset of rainfall before the commencement of the planting season as a result of prolonged dry season or lean period, they often face unpredictable weather which comes with high frequency and intensity of rainfall in the second modal distribution that often leads to flash flooding and destruction of livelihoods (Adeoti et al., 2010). Thus, the level of vulnerability exposes the agricultural livelihoods of farmers to catastrophic conditions with grave implications for sustainability of the food and farming systems. There was a consistent pattern of increases in the magnitude of land area under food poverty with high rainfall variability.

The study reveals that the agricultural livelihoods of farmers in Nigeria are threatened in the face of rainfall variability. The situation could necessitate constant adaptation practices to changing rainfall patterns, with unpredictable outcomes, even as early warming systems are advocated for effective minimization of the vagaries of the weather. Similarly, the results revealed that undesirable level of food poverty is implicated by a high level of vulnerability to rainfall variability in Nigeria. The National Adaptation Strategy and Plan of Actions (NASPA) is a climate change specific policy response in Nigeria (Olayide et al., 2016a). Such policy response should however, focus on specific hotspots of context and climate vulnerability that can ensure proper targeting of resources. The findings of this study are relevant for proper implementation of NASPA in Nigeria.

Although, the desirability of achieving food security and environmental resilience by fostering agri-green economy and improvement of agricultural livelihoods (FMARD, 2016; Garrity et al., 2010; Dixon et al., 2001) is a top priority of government in Nigeria, such a priority could become a mirage if the level of current vulnerability status as presented in this paper is negleted. The current understanding (as informed by the findings) provides that there are connections in the desirability and vulnerability within the continuum of sustainability with implications for sustainable agricultural production and food security in Nigeria. Overall, the results suggest that rainfall variability is re-inforcing food poverty in Nigeria. Thus, supporting the study hypothesis, and corroborating existing literature on the phenomenon of geography of economic development (World Bank, 2009) which underscores the concentration poverty or wealth at specific locations (World Bank, 2009). But the findings of this paper have revealed that such concentration of wealth may be amplified by level of vulnerability in the economic resource-based (in this instance, a rain-fed agricultural economy). This paper modeled vulnerability of rain-fed agrarian economy to rainfall variability.

6. Conclusion and recommendations

Rainfall variability and food poverty are intricately linked as empirical evidence of new methodological frameworks on vulnerability assessment focusing on contextual and climatic vulnerability and application of geographical information systems revealed in this paper. The analysis in this paper provides empirical evidence on the theoretical underpinning of contextual vulnerability and climatic vulnerability. The findings revealed the agro-ecological and socio-economic dimensions in the hotspots of rainfall variability and food poverty in Nigeria. These results underscore the vulnerability of specific parts of the country to the impacts of rainfall variability and food poverty.

The paper reveals specific locations of desirability (including magnitude of land area covered) - with low to moderate rainfall variability and low to moderate food poverty, and locations of undesirability with high rainfall variability and high food poverty. These variations in (un)desirability have inherent south-north dichotomy, differential socio-economic status and agro-ecological

dimensions. Hence, the paper established important linkage between rainfall variability and food poverty in Nigeria.

Specifically, the locations low rainfall variability and low food poverty (LRVLFP) comprised Rivers, Imo, Abia, Anambra, Nassarawa, FCT-Abuja, and Niger. The least desirable vulnerability outcomes of high rainfall variability and high food poverty (HRVHFP) comprised Sokoto, Katsina, Jigawa, and Yobe. Therefore, there is the need for climate change adaptation policy strategies at the different hotspots and domains of vulnerability (especially, HRVHFP). Such a policy framework should address food poverty with workable agro-technology (including small-scale irrigation, rainwater harvesting, and greenhouse farming) in order to engender a sustainable agrarian economy in Nigeria. The findings also give direction for appropriate policy interventions on food poverty reduction strategies which may include climate-smart agricultural practices. In addition, farmers involved in primary production system could exit the production stage and be more involved in assemblage and processing value chain nodes as well as provision of secondary services in the sub-sector of the agricultural system.

Further, there are potentials for synergy in the country for an effective agro-meteorological monitoring system of agricultural production and food systems. The locations and domains with desirable (low to moderate) rainfall variability and food poverty outcomes could be harnessed as food baskets of the nation by prioritising the agricultural production systems for national comparative advantage, such that there would be effective value chain development, including an efficient transport system. The domains with high vulnerability outcomes (high rainfall variability and high food poverty) should also be harnessed for their competitive advantage to include the establishment of processing industries to complement the value chain development in locations of desirable vulnerability outcomes (through vertical and horizontal integrations) and expansion of off-farm activities especially as climate change leads to shortage of the length of growing period or reduction in primary on-farm activities.

It is equally apposite to consider agro-climatic outcomes (rainfall variability) and socio-economic outcomes (food poverty) factors as sustainability issues in sustainable agricultural production and food poverty reduction strategies in Nigeria. The findings have provided empirical evidence, both for medium and long-term planning of agricultural production systems and food poverty reduction in Nigeria. Hence, the empirical and methodological approaches of this study could provide the basis for rethinking these sustainability issues.

Acknowledgements

This research is a follow up to the post-doctoral research fellowship, funded by the Department for International Development (DfID) under the Climate Impact Research Capacity and Leadership Enhancement (CIRCLE) programme. We are grateful to our respective institutions (the University of Ibadan, Nigeria and the International Institute of Tropical Agriculture, Ibadan, Nigeria) for providing conducive environments for research collaboration and training. We are also thankful to anonymous reviewers for useful comments and suggestions.

References

Adeoti, A., Olayide, O., Coster, A., 2010. Flooding and welfare of Fisher's household in Lagos state, Nigeria. J. Hum. Ecol. 32 (3), 161–167.

Ahmeda, S.A., Diffenbaugh, N.S., Hertel, T.W., Lobell, D.B., Ramankutty, N., Rios, A.R., Rowhani, P., 2011. Climate volatility and poverty vulnerability in Tanzania. Global Environ. Change 21, 46–55. https://doi.org/10.1016/j.gloenvcha.2010.10.003.

Brugère, C., De Young, C., 2015. Assessing Climate Change Vulnerability in Fisheries and Aquaculture Available Methodologies and Their Relevance for the Sector. Food and Agriculture Organization of the United Nations, Rome.

Cervigni, R., Valentini, R., Santini, M., 2013. Toward Climate-resilient Development in Nigeria. Report No. 78262. The World Bank, p. 215.

Challinor, A.J., Wheeler, T.R., Garforth, C., Craufurd, P., Kassam, A., 2007. Assessing the vulnerability of food crop systems in Africa to climate change. Climatic Change 83 (3), 381–399. ISSN 0165-0009.

Christiaensen, L., Demery, L., Kühl, J., 2006. The Role of Agriculture in Poverty Reduction: an Empirical Perspective, pp. 1–49. World Bank Policy Research Working Paper 4013 (September).

Cooper, P.J.M., Dimes, J., Rao, K.P.C., Shapiro, B., Shiferaw, B., Twomlow, S., 2006. Coping Better with Current Climatic Variability in the Rain-fed Farming Systems of Sub- Saharan Africa: a Dress Rehearsal for Adapting to Future Climate Change? Global Theme on Agroecosystems Report No. 27. PO Box 29063-00623. International Crops Research Institute for the Semi Arid Tropics, Nairobi, Kenya, p. 24.

DFID, (Department for International Development), 1999. Sustainable Livelihoods Guidance Sheets. Available at: http://bit.ly/1ucuqLO. (Accessed 3 August 2015).

Dixon, J., Gulliver, A., Gibbon, D., Hall, M., 2001. Farming Systems and Poverty: Improving Farmers' Livelihoods in a Changing World. Available at: http://bit.ly/1dDekBW.

Federal Government of Nigeria (FGN), 2013. Nigeria Post Disaster Needs Assessment of 2012 Floods Document.

Federal Ministry of Agriculture and Rural Development (FMARD), 2016. The Agriculture Promotion Policy (2016 – 2020), p. 59. Abuja, Nigeria.

Filho, W.L., Bönecke, J., Spielmann, H., Alves, F., De Carvalho, M.L., Nagy, G.J., 2018. Climate change and health: an analysis of causal relations on the spread of vector-borne diseases in Brazil. J. Clean. Prod. 177, 589–596. https://doi.org/10.1016/j.jclepro.2017.12.144.

Fischer, G., Shah, M., Tubiello, F.N., Van Velhuizen, H., 2005. Socio-economic and climate change impacts on agriculture: an integrated assessment, 1990–2080. Phil. Trans. Biol. Sci. 360 (1463), 2067–2083, 2005 Nov 29.

Fjelde, H., von Uexkull, N., 2012. Climate triggers: rainfall anomalies, vulnerability and communal conflicts in sub-Saharan Africa. Polit. Geogr. 31, 444–453.

Funk, C., Peterson, P., Landsfeld, M., Pedreros, D., Verdin, J., Shukla, S., Husak, G., Rowland, J., Harrison, L., Hoell, A., Michaelsen, J., 2015. The climate hazards infrared precipitation with stations—a new environmental record for monitoring extremes. Sci. Data 2, 150066. https://doi.org/10.1038/sdata.2015.66 (2015).

Garrity, D.P., Akinnifesi, F.K., Ajayi, O.C., Weldesemayat, S.G., Mowo, J.G., Kalinganire, A., Larwanou, M., Bayala, J., 2010. Evergreen Agriculture: a robust approach to sustainable food security in Africa. Food Sec. 2 (2010), 197–214. https://doi.org/10.1007/s12571-010-0070-7.

Gentle, P., Maraseni, T.N., 2012. Climate change, poverty and livelihoods: adaptation practices by rural mountain communities in Nepal. Environ. Sci. Pol. 21, 24–34. August 2012. https://doi.org/10.1016/j.envsci.2012.03.007.

Hahn, M.B., Riederer, A.M., Foster, S.O., 2009. The Livelihood Vulnerability Index: a pragmatic approach to assessing risks from climate variability and change: a case study in Mozambique. Global Environ. Change 19 (1), 74–88. February 2009. https://doi.org/10.1016/j.gloenvcha.2008.11.002.

Hardoy, J., Pandiella, G., 2009. Urban poverty and vulnerability to climate change in Latin America. Environ. Urbanization 21 (1), 203–224. First Published April 1, 2009. https://doi.org/10.1177/0956247809103019.

Harris, I., Jones, P.D., Osborn, T.J., Lister, D.H., 2014. Updated high-resolution grids of monthly climatic observations—the CRU TS3.10 Dataset. Int. J. Climatol. 34, 623–642.

Heltberg, R., Jorgensen, S.L., Siegel, P.B., 2008. Climate Change, Human Vulnerability, and Social Risk Management. Social Dimensions of Climate Change. World Bank Social Development Department, Washington, D.C. February.

Hertel, T.W., Rosch, S.D., 2010. Climate Change, Agriculture and Poverty. Policy Research Working Paper 5468. The World Bank, p. 55.

Hope, K.R., 2009. Climate change and poverty in Africa. Int. J. Sustain. Dev. World Ecol. 16 (6), 451–461. https://doi.org/10.1080/13504500903354424.

Intergovernmental Panel on Climate Change (IPCC), 2015. Climate change 2014: synthesis Report. In: Core Writing Team, Pachauri, R.K., Meyer, L.A. (Eds.), Contribution of Working Groups I, II and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change. IPCC, Geneva, Switzerland, p. 151. First published in 2015.

Kristjanson, P., Neufeldt, H., Gassner, A., Mango, J., Kyazze, F.B., Desta, S., Sayula, G., Thiede, B., Förch, W., Thornton, P.K., Coe, R., 2012. Are Food Insecure Smallholder Households Making Changes in Their Farming Practices? Evidence from East Africa. Food Security.

Kurukulasuriya, P., Mendelsohn, R., Hassan, R., Benhin, J., Deressa, T., Diop, M., Eid, H.M., Fosu, K.Y., Gbetibouo, G., Jain, S., Mahamadou, A., Mano, R., Kabubo-Mariara, J., El- Marsafawy, S., Molua, E., Ouda, S., Ouedraogo, M., Sene, I., Maddison, D., Seo, S.N., Dinar, A., 2006. Will African agriculture survive climate change? World Bank Econ. Rev. 20, 367–388.

Legg, C., 2007. Targeting agricultural research for development in Tanzania: an example of the use of GIS for ex ante impact assessment at IITA. In: Alene, A.D., Manyong, M.V., Abele, S., Sanogo, D. (Eds.), Assessing the Impact of Agricultural Research on Rural Livelihoods: Achievements, Gaps, and Options. Scientific Papers Presented at the Twenty- Sixth Conference of the International Association of Agricultural Economists, 12–18 August 2006, Brisbane, Australia. IITA, Ibadan, Nigeria, p. 80.

Manyong, V.M., Ikpi, A., Olayemi, J.K., Yusuf, S.A., Omonona, B.T., Okoruwa, V.,

Idachaba, F.S., 2005. Agriculture in Nigeria: Identifying Opportunities for Increased Commercialization and Investment. IITA, Ibadan, Nigeria, p. 159.
Mirza, M.M.Q., 2003. Climate change and extreme weather events: can developing countries adapt? Clim. Pol. 3, 233–248, 2003.
Montpellier Panel Report, 2015. The farms of change: African smallholder Responding to an Uncertain Climate Future. Published by Agriculture for Impact, p. 44.
Morton, J.F., 2007. The impact of climate change on smallholder and subsistence agriculture. Proc. Natl. Acad. Sci. 104 (50), 19680.
National Bureau of Statistics (NBS), 2016. Annual Abstracts of Statistics. Federal Republic of Nigeria Abuja, Nigeria.
National Bureau of Statistics (NBS), 2017. Contributions to Gross Domestic Products. Available at: http://nigerianstat.gov.ng/.
O'Brien, K., Eriksen, S., Nygaard, L.P., Schjolden, A., 2007. Why different interpretations of vulnerability matter in climate change discourses. Clim. Pol. 7 (1), 73–88.
Odufuwa, B.O., Adedeji, O.H., Oladesu, J.O., Bongwa, A., 2012. Floods of fury in Nigerian cities. J. Sustain. Dev. 5 (7), 69–79.
Olayide, O.E., Tetteh, I.K., Porter, J.R., Popoola, L., 2016a. Review and analysis of vulnerability to rainfall variability and policy responses to agricultural water supply in Nigeria. Journal of food. Agric. Environ. 14 (2), 152–155.
Olayide, O.E., Tetteh, I.K., Popoola, L., 2016b. Differential impacts of rainfall and irrigation on agricultural production in Nigeria: any lessons for climate-smart agriculture? Agric. Water Manag. 178, 30–36.
Olayide, O.E., Alabi, T., 2013. Unpacking the nexus in food prices, agricultural productivity and poverty. The geographic information systems approach. Afr. J. Sustain. Dev. 3 (1), 1–14 (2013). Available at: http://www.ajol.info/index.php/ajsd/article/view/93500.
Oppenheimer, M., Campos, M., Warren, R., Birkmann, J., Luber, G., O'Neill, B., Takahashi, K., 2014. Emergent risks and key vulnerabilities. In: Field, C.B., Barros, V.R., Dokken, D.J., Mach, K.J., Mastrandrea, M.D., Bilir, T.E., Chatterjee, M., Ebi, K.L., Estrada, Y.O., Genova, R.C., Girma, B., Kissel, E.S., Levy, A.N., MacCracken, S., Mastrandrea, P.R., White, L.L. (Eds.), Climate Change 2014: Impacts, Adaptation, and Vulnerability. Part a: Global and Sectoral Aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, pp. 1039–1099.
Raleigh, C., Jordan, L., Salehyan, I., 2008. Assessing the Impact of Climate Change on Migration and Conflict. World Bank, Washington, D.C.
Rosegrant, M.W., Koo, J., Cenacchi, N., Ringler, C., Robertson, R., Fisher, M., Cox, C., Garrett, K., Perez, N.D., Sabbagh, P., 2014. Food Security in a World of Natural Resource Scarcity: the Role of Agricultural Technologies. International Food Policy Research Institute (IFPRI), Washington, DC, p. 174.
Sanchez, P.A., 2000. Linking climate change research with food security and poverty reduction in the tropics. Agric. Ecosyst. Environ. 82 (1–3), 371–383. December 2000. https://doi.org/10.1016/S0167-8809(00)00238-3.
Sebastian, K., 2014. Atlas of African Agriculture Research and Development: Revealing Agriculture's Place in Africa. International Food Policy Research Institute (IFPRI), Washington DC.
Siwar, C., Alam, M., Murad, W., Al-Amin, A.Q., 2009. A review of the linkages between climate change, agricultural sustainability and poverty in Malaysia. Int. Rev. Bus. Res. Pap. 5 (6), 309–321. November 2009.
United Nations, 2015. Transforming Our World: the 2030 Agenda for Sustainable Development. United Nations Sustainable Development Solution Network (UNsdsn), USA. Available at: http://unsdsn.org.
Vermeulen, S.J., Aggarwal, P.K., Ainslie, A., Angelone, C., Campbell, B.M., Challinor, A.J., Hansen, J.W., Ingram, J.S.I., Jarvis, A., Kristjanson, P., Lau, C., Nelson, G.C., Thornton, P.K., Wollenberg, E., 2012. Options for support to agriculture and food security under climate change. Environ. Sci. Pol. 15 (2012), 136–144.
World Bank, 2008. World Development Report (WDR) 2008. Agriculture for Development. The World Bank, Washington, DC, p. 386.
World Bank, 2009. World Development Report (WDR). Reshaping Economic Geography. The World Bank, Washington, DC, p. 386.
World Development Report, 2010. Development and Climate Change. World Bank, Washington, D. C.